

ON ORBIT ANOMALY RESEARCH

Goals of Research

- Identify areas of focus for current and future IV&V projects based off of trends observed from cross mission anomaly study.
- Support current IV&V analysis on projects using heritage code by identifying anomalies specifically related to areas of reuse.
- Increase the value added for IV&V by:
 - + Identifying anomalies that occurred in areas of past IV&V coverage
 - + Recognizing areas of potential risk in IV&V's analysis process based off of the anomalies
 - + Generating lessons learned to improve the quality of analysis in the future.

CHIPSat Questions

- 1) Is the anomaly software related?
- 2) Could software have prevented or reduced the impact of this anomaly?
- 3) Was the anomaly within the scope of IV&V's analysis effort for the project?
- 4) How can the IV&V Program use these findings to improve processes and analysis efforts in the future?

Command and data handling (6 anomalies)

The single board computer reset multiple times due to radiation flares exceeding the radiation hardness of the spacecraft's hardware. Some science data being stored was lost during each upset.

- 1) Not software related
- 2) Software based fault protection should have been in place to monitor for high radiation conditions and could have reduced the impact of the anomaly.
- 3) IV&V raised concerns about radiation and the lack of an adequate response. The project ensured that appropriate measures were in place to handle any situation

4) Lessons Learned

- NASA IV&V personnel need to understand the impact of environmental conditions related to the spacecraft on which they are working. Further, personnel should ensure that there are measures in place to mitigate problems that may arise because of these environmental conditions (radiation, heat, cold, light, etc.).

Some questions to ask:

- i. In what ways could this spacecraft be affected by each environmental condition?
- ii. Is there any flight software on the spacecraft related to direct control over systems whose purpose is managing environmental conditions? Is the software adequate?
- iii. What kind of software based fault protection is/should be in place for monitoring environmental conditions that could affect the craft? How does/should the software handle adverse conditions?

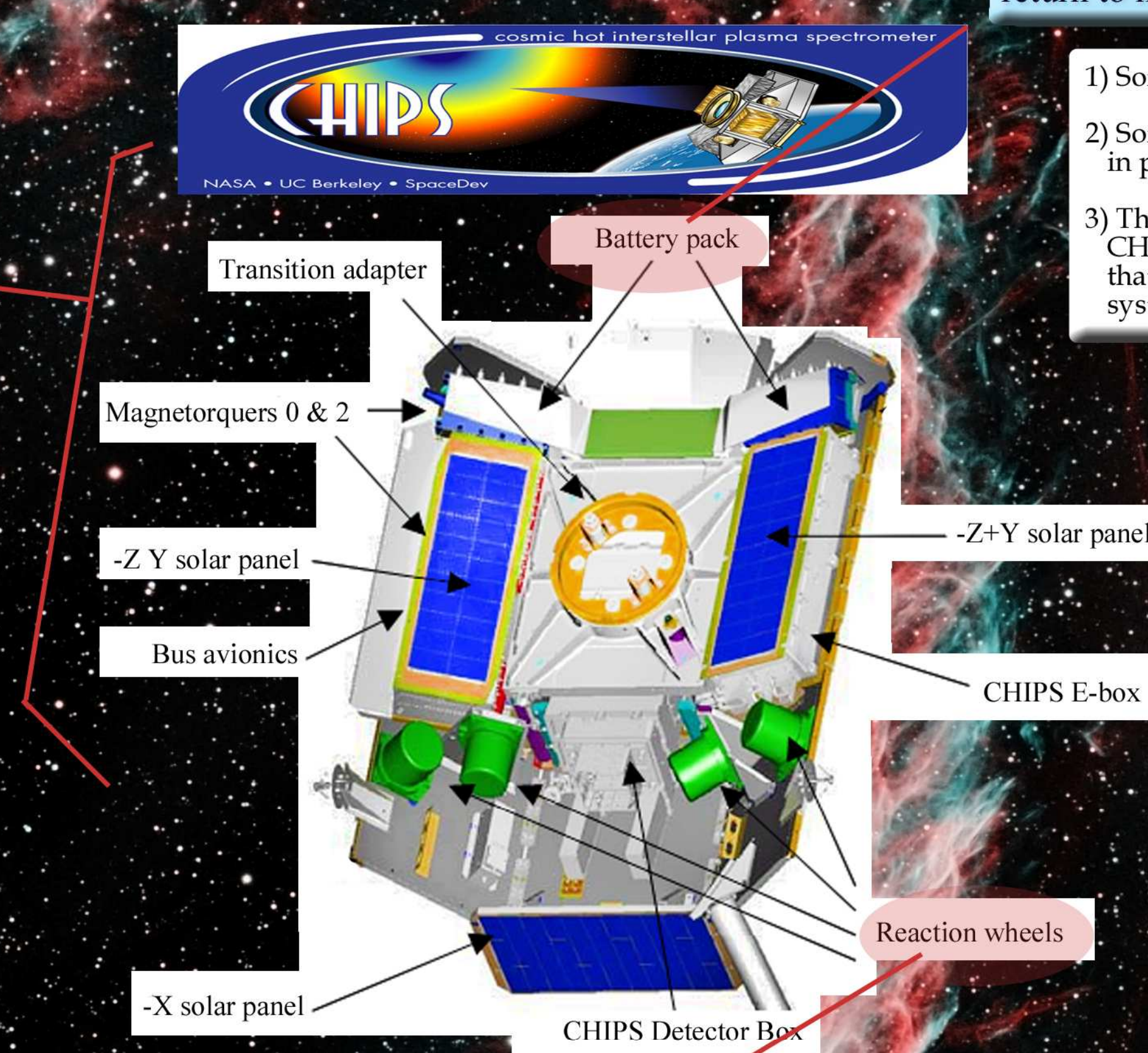
Electrical / Power System Anomaly

A "noisy" telemetry system produced a spurious data point causing the power system to think Battery Pack A was fully charged. The system then placed BP A into trickle charge mode. It took a complete discharge cycle for the battery to return to normal charge.

- 1) Software did not directly cause the anomaly.
- 2) Software based fault protection should have been in place to validate data points received by the spacecraft.
- 3) This aspect of the spacecraft was not covered in the CHIPSat IA. However, our anomaly research effort indicated that there was a missing requirement related to the power system's verification of signals.

4) Lessons Learned

- A spacecraft's flight software makes mission critical decisions every minute based on data points received from external input. Data points, especially those which are used by flight software to perform mission critical functionality, should be verified by flight software to prevent erroneous paths of execution. In the case of CHIPSat, the A/CDH should have had functionality in place to verify that the data point received was accurate before executing further operations.



ACS Anomalies (Wheels)

The spacecraft entered a tumble after a reaction wheel failed. A redundant wheel was substituted and the spacecraft returned to its nominal state.

- 1) It was undetermined if software caused the anomaly.
- 2) Software should have been able to reduce the amount of time that the spacecraft was in tumble, as the only way for CHIPSat to recover from a tumble scenario was through ground intervention.
- 3) The true root cause was undetermined, so IV&V's involvement with the affected area is ambiguous.

4) Lessons Learned

- Redundancy in mission critical systems is a must. IV&V should verify that a protocol is in place to handle failure of mission critical systems, whether they reside in hardware or software, in a way that causes the least impact to the mission. In the case of one anomaly, the broken wheel was able to be replaced without significantly impacting the mission.
- Be very clear on what was verified and validated in respect to the project, especially regarding question 3 analysis (how does the system perform under adverse conditions).
 - i. In the case of CHIPSat, IV&V performed an independent assessment. Due to the nature of the assessment (far from a full IV&V effort) and the limited amount of documentation present in the analysis, it was difficult to precisely determine what IV&V covered

Some questions to ask:

- i. Can the flight software identify faults occurring in mission critical and safety critical systems in real-time?
- ii. What is the response of the flight software covering critical / safety systems?
- iii. Is the response of these systems adequate?
- iv. Does this response take into account systemic trends?

- Utilize Subject Matter Experts to analyze the mission critical components of all IV&V analysis efforts.
- Could the issues leading to these anomalies have been prevented by the use of a Subject Matter Expert by the development team?
- All missions, regardless of funding source and size, should have baseline fault protection systems to prevent loss of mission due to easily preventable and predictable failures.

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